

# THE OSTEOLOGICAL CHARACTERS OF THE FISHES OF THE SUBORDER PERCESOCES.

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A study of the skeletons of several representatives of the families Atherinidæ, Mugilidæ, and Sphyrænidæ, which are grouped together under the suborder Percesosces, reveals the fact that they are not so closely allied to each other as their external similarity would lead one to suppose.

The specimens from which my observations were made are adult examples of *Atherinopsis californiensis*, *Menidia notata*, *Mugil cephalus*, and *Sphyræna argentea*.

In examining the crania of these species attention is attracted at once to the fact that in all of them the epiotics are developed into long, thin processes which divide into more or less bristlelike filaments.

There is little else in purely internal characters whereby to differentiate these families as a group from other Acanthopteri. In order to so differentiate them we must turn to the well-known external characters—a spinous dorsal in conjunction with the abdominal ventral fins, high pectoral fins, and unarmed opercles.

If, however, we eliminate the Sphyrænidæ (which, on account of its fanglike teeth, set in deep sockets, its separate superior pharyngeals of third and fourth branchial arches, its lack of parapophyses on anterior vertebræ, and other characters, we may well be justified in doing) and place it in a separate superfamily coordinate with that in which we place the Mugilidæ and Atherinidæ, we shall then have remaining a more compact group, notwithstanding the great difference in number of vertebræ in the two families of which it is composed.

In it we find the parapophyses developed on all the abdominal vertebræ, the anterior neural spines flattened, wide and thin, the supraclavicle very small, the superior pharyngeals of each side of the third and fourth branchial arches anchylosed, and the teeth small, not fanglike and set in sockets.

## DIAGNOSIS OF THE SUBORDER PERCESOCES.

Two dorsal fins, the first spinous and more or less remote from the second; ventral fins abdominal, with 1 spine and 5 rays; third and fourth superior pharyngeals of each side separate or ankylosed; lower pharyngeals separate; pectorals elevated, nearly on a level with upper part of clavicle; epiotics of adult produced backward and more or less divided into bristlelike filaments; myodome present, opened or closed posteriorly; opercles unarmed; parietals separated by supraoccipital; supraoccipital crest developed posteriorly, not extending above level of balance of cranium; postclavicle of superior and inferior parts; anterior interhæmal not differentiated; epipleurals present; coronoid bone present;<sup>1</sup> suborbital ring without suborbital shelf.

## DIAGNOSIS OF THE SUPERFAMILY ATHERINOIDEA.

Cleft of mouth not wide; teeth, when present, small, not set in sockets; maxillary without supplemental bone; third and fourth superior pharyngeals of each side ankylosed; supraclavicle reduced in size; lower limb of posttemporal attached to opisthotic by ligament or suture; exoccipitals not meeting above basioccipital; alisphenoids not meeting; ethmoid normal, not overlying prefrontals and vomer or extending to lateral edge of rostrum; anterior neural spines laterally flattened; parapophyses developed on all abdominal vertebrae.

## DIAGNOSIS OF THE FAMILY ATHERINIDÆ.

Lower limb of post-temporal attached to opisthotic by ligament; basisphenoid developed; myodome opening to exterior posteriorly; region about foramen magnum not produced; superior pharyngeals typical in shape, bearing teeth; vertebrae numerous, from 45 to 52; first dorsal with from 3 to 8 spines; anal with 1 spine.

## DIAGNOSIS OF THE FAMILY MUGILIDÆ.

Lower limb of post-temporal attached to cranium by dentate suture; basisphenoid absent; myodome not opening to exterior posteriorly; foramen magnum region produced; superior pharyngeals of complex shape, not bearing teeth; vertebrae few in number, about 24; first dorsal with about 4 spines; anal with 2 or 3 spines.

<sup>1</sup> This character seems to have been made too much of by the systematists and not enough of by the anatomists. Whether it is homologous with the coronoid as it occurs in some reptiles, or is one of the osteological peculiarities common to fishes, or whether it is developed with age, being the ossified end of the ligament that is attached to it, I will not attempt to say with the material at hand. The last supposition seems to be the least tenable, since the ossification is not a gradual transition from cartilage to bone, as we would expect in that case, but takes the form of a distinct bone larger than the end of the ligament. I find it present in nearly every species examined (my material being adult examples), among them the following miscellaneous genera: *Amiurus*, *Cyprinus*, *Lucius*, *Alosa*, *Holocentrus*, *Pomoxys*, *Lobotes*, *Roccus*, *Caranx*, *Archosargus*, *Neomænis*, *Tautoga*, *Pomatomus*, *Rachycentron*, *Scorpenichthys*, *Lopholatilus*, *Melanogrammus*, and *Gadus*.

## DIAGNOSIS OF THE SUPERFAMILY SPHYRENOIDEA.

.Cleft of mouth wide; teeth fanglike, some of them set in deep sockets, large teeth on palatines; maxillary with supplemental bone; third and fourth superior pharyngeals separate; supraclavicle not reduced in size; lower limb of post-temporal not attached to opisthotic by suture; exoccipitals not meeting above basioccipital; alisphenoids meeting; ethmoid a thin plate, entirely superior, extending to and forming edge of rostrum; anterior neural spines normal; parapophyses not developed on anterior vertebræ.

The characters of the family Sphyrænidæ are included in the foregoing diagnosis.

## OSTEOLOGY OF ATHERINOPSIS CALIFORNIENSIS.

Exoccipitals not meeting above basioccipital, thus leaving the latter to form floor of foramen magnum.

Basioccipital and exoccipitals not much produced posteriorly.

Supraoccipital crest not projecting above superior level of skull; its posterior edge somewhat broken up and ragged.

Parietals widely separated by supraoccipital.

Epitotics produced backward, spreading out into thin, flat, horizontal processes, which are much divided and ragged, though scarcely "bristle-like," as in *Mugil* and *Sphyræna*.

Opisthotics with a projection to which lower limb of post-temporal is attached by ligament.

Pterotics extending back as thin horizontal shelves of bone.

Sphenotics well developed, their front edge continuous with edge of frontals.

Alisphenoids not meeting.

Anterior opening into brain case large.

Basisphenoid well developed, wholly in front of basis cranii and not continuous with it. Supported directly by prootics and slightly by alisphenoids. Its process strongly joined to parasphenoid, extending posteriorly into myodome.

Myodome large, opening to the exterior at its posterior end through a small foramen at end of parasphenoid.

Vomer convex on lower surface; its anterior edge produced at the middle; trilobate in the young and pierced by a network of holes.

Ethmoid wholly superior, being a simple, flat, thin bone supported at its anterior edge by vomer and sending some slender filaments of bone under frontals. The large space beneath it is filled by cartilage.

Frontals extending well back over about half of superior portion of supraoccipital.

Metapterygoid united to hyomandibular by a deeply dentate suture.

Pterygoid very much reduced in size—a mere splint of bone.

Bones of opercular apparatus large.

Opercular sending a spine forward in front of hyomandibular.

Dentary without the typical cavity into which the meckelian cartilage and end of articular runs anteriorly.

Angular present.

Coronoid bone present.

Post-temporal not especially firmly attached. Upper limb attached to base of epiotic process, the outer side rather loosely to pterotic process. The thin, flat lower limb attached to process from opisthotic by a short ligament.

Supraclavicle very short, its upper end scarcely reaching above upper end of clavicle.

Hypercoracoid placed high on clavicle. Its foramen as described under *Mugil*.

Hypercoracoid at upper end more broadly joined to clavicle than that of *Mugil*. Its lower end attached to a high median vertical wing between inner and outer edge of clavicle.

Actinosts very short, two joined to each the hypocoracoid and hypercoracoid. Two or three upper rays of pectoral fin working directly on hypercoracoid.

Postclavicle consisting of a superior and inferior part.

Pelvic bones higher than wide. A spinelike process sent upward from the outer edge of each of them.

Interneurals of spinous dorsal compressed into thin plates without descending spines between the neural spines. First and second interneurals not fused.

Interneurals of soft dorsal with spines between the neural spines as usual. In front of them an auxiliary interneural is attached.

Front of anal fin free under abdominal cavity.

Interhæmals subequal, growing slightly longer anteriorly. The first not differentiated.

Three basibranchials present, united to each other by sutures.

Suspensory pharyngeal<sup>1</sup> of first branchial arch present.

Second arch<sup>2</sup> with a small toothed superior pharyngeal.

Superior pharyngeals of third and fourth arches fused into a large elliptical bone. A transverse groove or suture is present, probably indicating separate pharyngeals of the third and fourth arches in the young.

Hyoid apparatus typical.

Branchiostegals six; all attached to outer surface of hyoid.

Nasals present; thin and short.

Suborbital ring apparently not complete, one bone besides preorbital being at anterior end and one at posterior, while directly beneath eye there are no bones in evidence.

Premaxillary wide at its lower end, while maxillary is subequal throughout its length, which is a transposition of the usual condition.

Maxillary without supplemental bone.

<sup>1</sup> Here so called because its function is usually that of suspending the branchial arches from the cranium. It is typically styloform and toothless.

<sup>2</sup> One side only of branchial arches considered in describing superior pharyngeals.

Vertebrae, in number, with hypural, 52. In another specimen, 50. Impossible to draw a line between abdominal and caudal vertebrae. Twenty-fifth and succeeding posterior vertebrae with an arch between each pair of parapophyses, behind which parapophyses gradually become longer, thinner, and wider, till at the thirty-fourth their tips approach each other and touch, forming a gradually decreasing tunnel continued to the forty-first, where it becomes obsolete. This tunnel is probably for reception of posterior end of air bladder. Only those vertebrae from the forty-first backward have typical hæmal spines.

Anterior neural spines, flattened into thin plates, much as in *Mugil*.

Parapophyses on all abdominal vertebrae, including atlas. Subequal in size and directed at about the same angle.

Superior anterior and posterior parapophyses normally developed; not with spines, as in *Mugil*.

Inferior posterior zygapophyses developed on a few of the middle vertebrae.

Hypural assisted in supporting caudal fin by spines of next preceding four or five vertebrae.

Ribs transversely flattened.

Epipleurals present, typical.

#### OSTEOLOGY OF MUGIL CEPHALUS.

Cranium short and broad, its upper surface smooth and convex.

Exoccipitals not meeting above basioccipitals, thus leaving the latter to form floor of foramen magnum.

Exoccipitals and basioccipitals produced backward, elongating the foramen magnum tunnel-like.

Supraoccipital crest produced backward, somewhat broken up or ragged posteriorly. Not extending above superior level of skull.

Parietals widely separated by supraoccipital.

Epiotics produced far backward, spreading out into thin, flat, horizontal processes which divide into bristlelike filaments.

Opisthotics sending back a rod of bone to which lower limb of post-temporal is united by suture.

Pterotics extending backward farther than usual as thin, flat projections.

Sphenotics well developed, forming large lateral projections from side of cranium. A short distance in front of them the frontals are laterally produced, leaving deep conspicuous notches over orbital region.

Alisphenoids not meeting.

Anterior opening into brain case large.

Basisphenoid absent.

Mydome present, not opening to exterior at its posterior end. The anterior edge of basis cranii some distance back from mouth of anterior opening into brain case.

Vomer divided anteriorly into two prominent horns by a deep rounded notch.

Ethmoid almost directly above vomer, similarly indented, but by a shallower notch.

Frontals not extending very far back, exposing underlying supra-occipital nearly to its anterior end, which reaches about middle of cranium.

Pterygoid reduced in size. Suspensorium otherwise typical.

Bones of opercular apparatus all large.

Opercular rolled over toward cranium at upper edge.

Cavity in dentary for reception of articular not large.

Coronoid bone well developed.

Angular present.

Dentary becoming slender anteriorly.

Post-temporal very firmly attached. Its upper fork attached broadly to a rough surface at base of epiotic process. Lower fork attached to process of opisthotic by very deeply dentate suture, forming an integral rod of nearly uniform size from opisthotic to distal end of posttemporal. Suture at about middle of rod. At posterior end of posttemporal at base of forks the long pterotic process is strongly fastened, thus forming a tripod attachment for shoulder girdle, making post-temporal wholly immovable.

Supraclavicle so small that it admits upper end of clavicle to nearly reach to a level with lower end of posttemporal.

Clavicle with a downward-hooked process on inner anterior edge.

Hypercoracoid placed high on clavicle. Its foramen, though wholly contained within hypercoracoid, is so near its forward edge that it deeply notches edge of overlying clavicle.

Hypocoracoid falciform. Its inner upper corner but slightly touching clavicle, thence curving quickly away and only weakly attaching to it at its long lower end.

Actinosts short; three joined to hypercoracoid, one to hypocoracoid.

Pectoral fin placed high on shoulder girdle, two or three of its upper rays working directly on hypercoracoid.

Postclavicle of two pieces. The superior typically lamellate, the inferior rodlike, large, and strongly curved inward.

From the under side of the pubic bones near their union each sends a long slender bone forward, which tapers to a hair-like process.

First interneural of spinous dorsal enlarged and divided into two spines, though supporting only one dorsal spine.

Interneurals of soft dorsal slender and subequal.

First interhæmal of anal enlarged very slightly, though not elongated, and supporting two anal spines. Interhæmals graduated from behind forward.

Front of anal not free under abdomen.

In front of spinous dorsal are two peculiar supernumerary interneurals composed of two long, slender, contiguous splints of bone placed horizontally. At the middle of each a fork is sent down between the second and third and fourth and fifth neural spines respectively.

Apparently but two basi branchials ossified; both in front of third arch, the hypobranchials of which meet on a median line.

Suspensory pharyngeal represented only by a nodule of cartilage.

First epibranchial typical. The three succeeding ones of complex shape, somewhat turned back upon themselves with many curves and processes.

To superior part of second epibranchial a rather thick triangular superior pharyngeal is attached.

Superior<sup>1</sup> to all else is a large pharyngobranchial of very complex shape. It is attached to and above the last three epibranchials and even to and above pharyngobranchial of second arch. It is doubtless the anchylosed pharyngobranchials of third and fourth arches. For ease of describing, it may be said to consist of a superior and an inferior part. The inferior, to which the epibranchials are attached, runs straight back to last arch. Springing from its anterior end a thin, imperforate, saucer-shaped superior bone arches widely over it, projecting both laterally and posteriorly. This upper part is further supported at its middle, umbrellalike, by a ray of bone sent up from posterior end of inferior part.

Hyoid apparatus typical in number and arrangement of elements.

Branchiostegals six, two attached to epihyal, four to ceratohyal; all attached to outer surface of hyoid.

Maxillary and premaxillary rather narrow and slight. Premaxillary widened at lower end, and without supplemental bone. Respective sides of maxillary rather widely separated by unusually wide processes of premaxillary sent backward at its symphysis.

Nasals short and quadrangular in shape.

Suborbitals forming a narrow ring, through which is the usual sensory canal.

Preorbital triangular, its lower edge sharply dentate.

Vertebral formula: Abdominal 11, caudal 12, which, with the hypural, number 24.

First five vertebræ with neural spines flattened laterally and forming a more or less continuous crest.

Parapophyses very large; wide and thin at the edges. Developed on all abdominal vertebræ, growing gradually larger and more nearly horizontal anteriorly, until the third is reached, thence scarcely diminishing in size to the atlas.

A process developed from each anterior zygapophysis, which is ankylosed with its fellow of the opposite side, forming an arch over neural cord, and extending obliquely forward to neural spine.

A spine developed from each posterior zygapophysis pointing obliquely backward and overlapping outer edge of that from anterior zygapophysis.

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<sup>1</sup>The arches described as straightened out for examination, not as in natural position with the superior pharyngeals turned downward.

Inferior zygapophyses developed as large spines, each anterior spine the longer and pointing obliquely forward; each posterior pointing obliquely backward at right angles, meeting it at its middle.

Hypural assisted in supporting caudal fin by spines of two preceding vertebræ and two auxiliary spines substituting neural spine of first preceding vertebra.

First rib very small, placed on second vertebra. Second, two or three times as long and abruptly widened at its upper end. Others normal.

Four epipleurals only present. First placed on first vertebra, unaccompanied by a rib. Other three on first three ribs.

#### OSTEOLOGY OF SPHYRÆNA ARGENTEA.

Cranium elongate and narrow, forming a narrow isosceles triangle, as viewed from above.

Supraoccipital scarcely interposed between exoccipitals. Its crest extending far back as a thin plate of bone, dividing into numerous bristle-like filaments.

Exoccipitals meeting above basioccipital, completely surrounding foramen magnum.

Exoccipitals and basioccipital produced backward, elongating foramen magnum, which runs tunnel-like into brain cavity.

Parietals widely separated by supraoccipital, their posterior ends overlapping epiotics.

Epiotics extending backward in bristle-like filaments similar to supraoccipital.

Upper limb of posttemporal firmly attached to upper part of epiotic process rather than to main part of bone.

Opisthotics sending a spinelike process backward, to base of which lower limb of post-temporal rather loosely attaches itself by ligament.

Prootics produced anteriorly in a spinelike process.

Sphenotics large, separated from frontal at middle portion by a large foramen.

Alisphenoids meeting at their upper edges. They restrict the anterior opening into brain case to a comparatively small foramen.

Basisphenoid present, a foramen between it and basis cranii, its descending process reaching to and broadly attaching to parasphenoid.

Myodome present, not opening to exterior at posterior end.

Frontals elongate, covering two-thirds of length of skull.

Prefrontals very elongate, the olfactory foramen within their posterior fourth.

Ethmoid entirely superior in position, overlying anterior part of prefrontals and posterior part of vomer, forming edge of rostrum between prefrontals and vomer.

Nasals long, channeled rods of bone fully one third length of cranium firmly attached in a groove between frontals and prefrontals and continued along upper part of ethmoid and vomer.



Suborbital ring formed of a very large preorbital and the usual chain of small suborbitals tunneled with sensory canal.

Bones of suspensorium and opercular apparatus typical in their relative positions.

Palatine process very strong and heavy, its lower edge sharp, supporting a single row of teeth.

Metapterygoid rather thick, united by suture for whole length of its attachment with hyomandibular. No foramen between.

Symplectic attached to metapterygoid at its upper end by subdentate suture.

Angular present, rather small.

Coronoid bone well developed.

Maxillary and premaxillary so attached to each other as to allow little play between them. Maxillary with a well developed supplemental bone which bears a knob on its posterior edge.

Teeth of palatine and jaws, except anterior teeth of lower jaw and premaxillary, set deep in grooves, which are subdivided for each tooth forming semisockets.<sup>1</sup> The exceptions noted isolated and set in true sockets. The rooted portion of each tooth as great or greater than the exposed portion.

Clavicle turning forward at an angle slightly above pectoral fin.

Pectoral superior in position, its upper ray working directly upon hypercoracoid.

Actinosts moderate in size, all attached to hypercoracoid except half of lower one.

Hypercoracoid barely touching clavicle at its upper end, arching widely away from it and strongly attaching to it at its lower end. At its upper superior portion a process projects backward past end of actinosts.

Postclavicle consisting of two parts.

Supraclavicle of moderate size.

Hypohyals united to ceratohyals by sutures.

Glossohyal rod-like, rather stout and elongate.

Urohyal divided into three long processes extending backward beyond posterior ends of branchiostegals. These subdivided into bristle-like filaments.

Branchiostegals seven in number.

Basibranchials three in number, the anterior one in front of that of first arch, the posterior ones supporting both second and third arches.

Superior pharyngeals four, including the moderate suspensory pharyngeal, the two posterior forming an elongate ovate patch, but not anchylosed.

First two interneurals of spinous dorsal not anchylosed, as is commonly the case.

<sup>1</sup> Somewhat similar to the posterior teeth in the jaws of a crocodile.

Interhemals evenly graduated in length from behind forward, the anterior one not differentiated.

Vertebral formula: Abdominal, 13; caudal, 11, which, with the hypural, are 24.

Atlas short, the succeeding vertebræ elongate and rather smooth, without deep pits, and much constricted in the middle.

Anterior and posterior zygapophyses well developed.

Parapophyses not developed anterior to ninth vertebra.

Evidence apparent of hypural having been developed from two posterior vertebræ.

Hypural assisted in bearing caudal fin by spines from two preceding vertebræ and some detached auxiliary spines taking the place of neural spine of first preceding vertebra.

Lateral processes from hypural large and flat, forming a keel.

Last pair of ribs firmly anchylosed with last pair of parapophyses.

Epipleurals present.

#### EXPLANATION OF PLATES.

##### SIGNIFICANCE OF REFERENCE LETTERS USED ON PLATES.

[From drawings by Chloe Lesley Starks.]

<i>als.</i> Alisphenoid.	<i>pas.</i> Parasphenoid.
<i>bo.</i> Basioccipital.	<i>p.</i> Parietal.
<i>bs.</i> Basisphenoid.	<i>pro.</i> Prootic.
<i>epo.</i> Epiotic.	<i>pto.</i> Pterotic.
<i>e.</i> Ethmoid.	<i>pf.</i> Prefrontal.
<i>eo.</i> Exoccipital.	<i>spo.</i> Sphenotic.
<i>fr.</i> Frontal.	<i>so.</i> Supraoccipital.
<i>na.</i> Nasal.	<i>r.</i> Vomer.
<i>opo.</i> Opisthotic.	

#### PLATE I.

Superior views of the crania of *Sphyræna argentea*, *Atherinopsis californiensis*, and *Mugil cephalus*.

#### PLATE II.

Lateral views of the crania of *Sphyræna argentea*, *Atherinopsis californiensis*, and *Mugil cephalus*.

#### PLATE III.

Posterior views of the crania of *Sphyræna argentea*, *Atherinopsis californiensis*, and *Mugil cephalus*.